Simulation Evaluations of an Autonomous Urban Air Mobility Network Management and Separation Service

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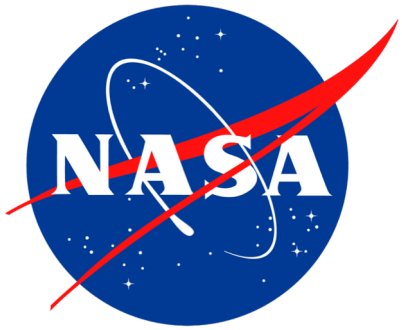

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Motivation

- Increased interest in Urban Air Mobility (UAM)
- New aircraft types and missions
- Extend airspace uses to high-density and mixed operations
- Paradigm shift towards greater levels of autonomy

Research Objectives

1) Develop a research platform to explore far-term UAM operations

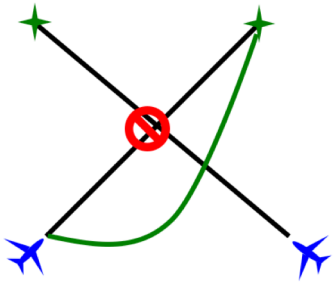
2) Build and evaluate a prototype of an autonomous network management and separation concept under different operational conditions

Outline

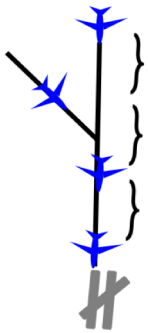
- Prototype Algorithm
- Methodology
- Simulation Results
- Summary
- Future Work

Prototype Algorithm

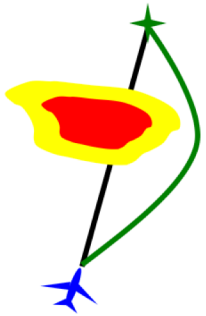
- Prototype extending NASA's autonomous AutoResolver algorithm
- Trajectory-based algorithm that iteratively performs automated



Conflict detection and resolution



Arrival spacing and metering

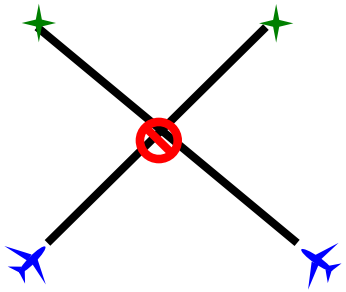


Weather avoidance

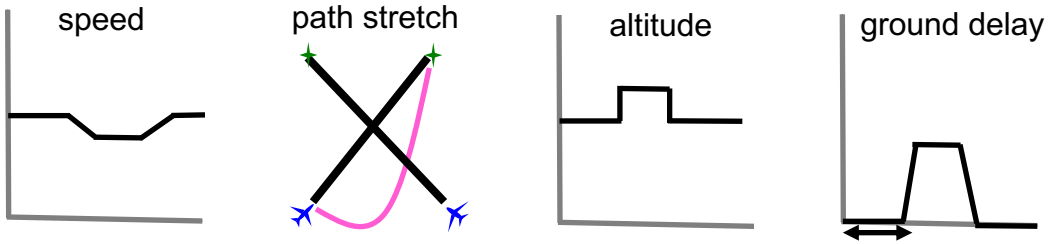
- Uses 4D aircraft projected trajectories
- Applied in past research in the Dallas-Fort Worth metroplex
  [Erzberger et al., 2012,2016][Nikoleris et al.,2014,2016][Lauderdale et al.,2011,2018]

Prototype Algorithm

- AutoResolver capabilities for UAM operations
  - Separation assurance to avoid losses of separation (LOS)

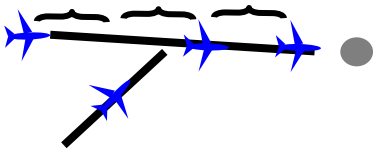


Prediction of a LOS



Resolution types for a LOS

  - Arrival management to avoid scheduling/sequencing conflicts (SEQ)



Prediction of a SEQ

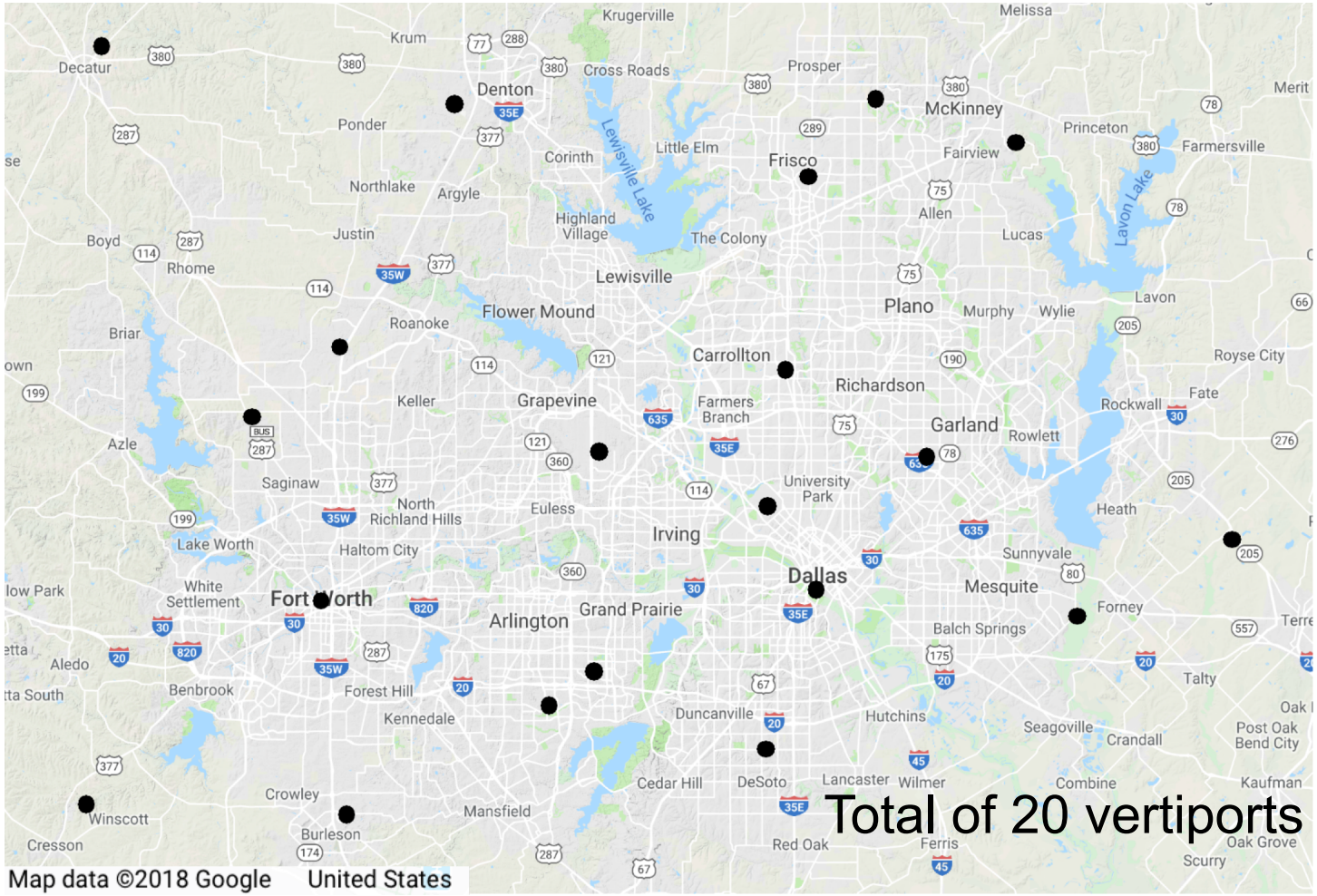
Path stretch, speed, ground delay

Resolution types for a SEQ

- Generates conflict free and efficient trajectory resolutions
- Picks and issues autonomously best resolutions to aircraft

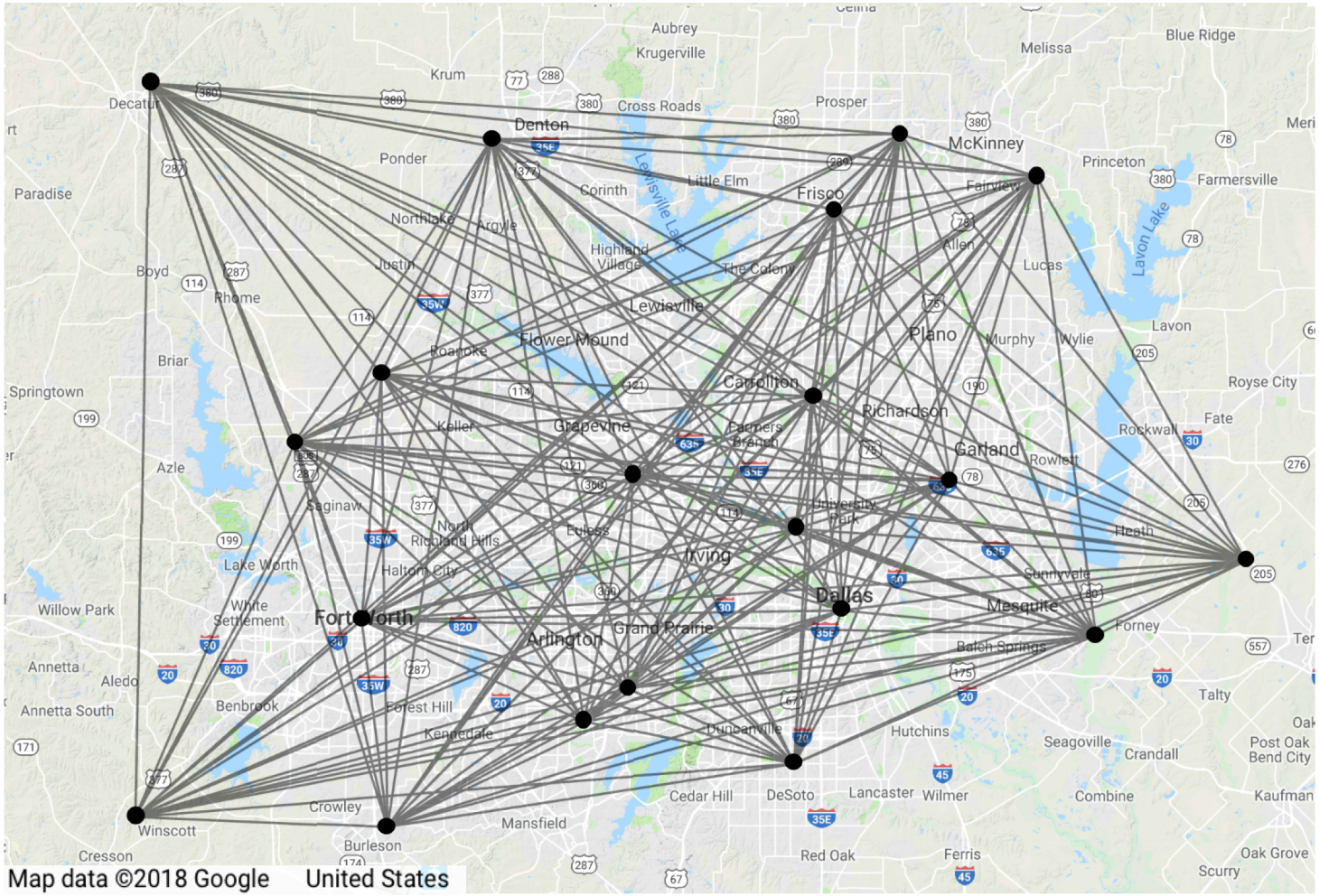
Methodology

Airspace Details



Methodology

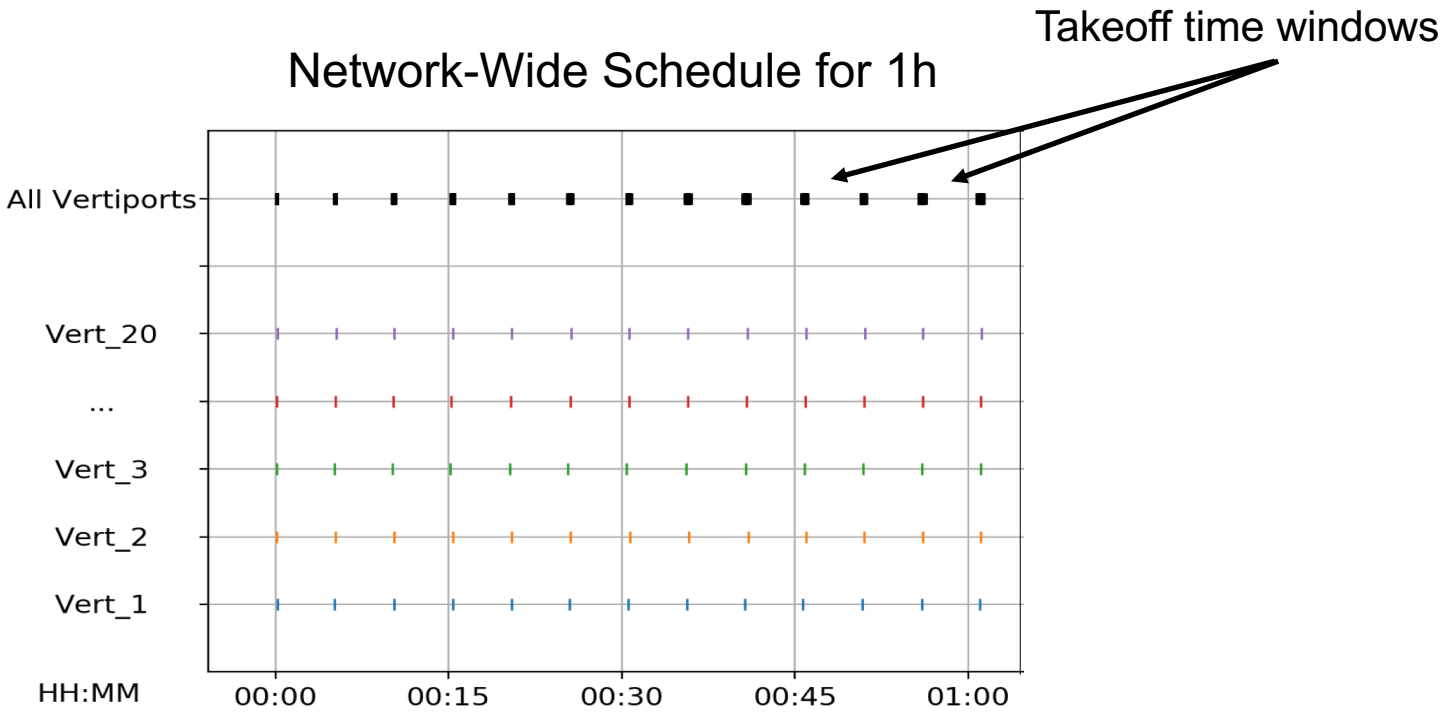
Flight Route Network



Methodology

Network-Wide Traffic Schedule

- 1 takeoff every 5min at all vertiports
- Sample takeoff time uniformly distributed over [0,10]s
- 2h traffic period: 450 flights

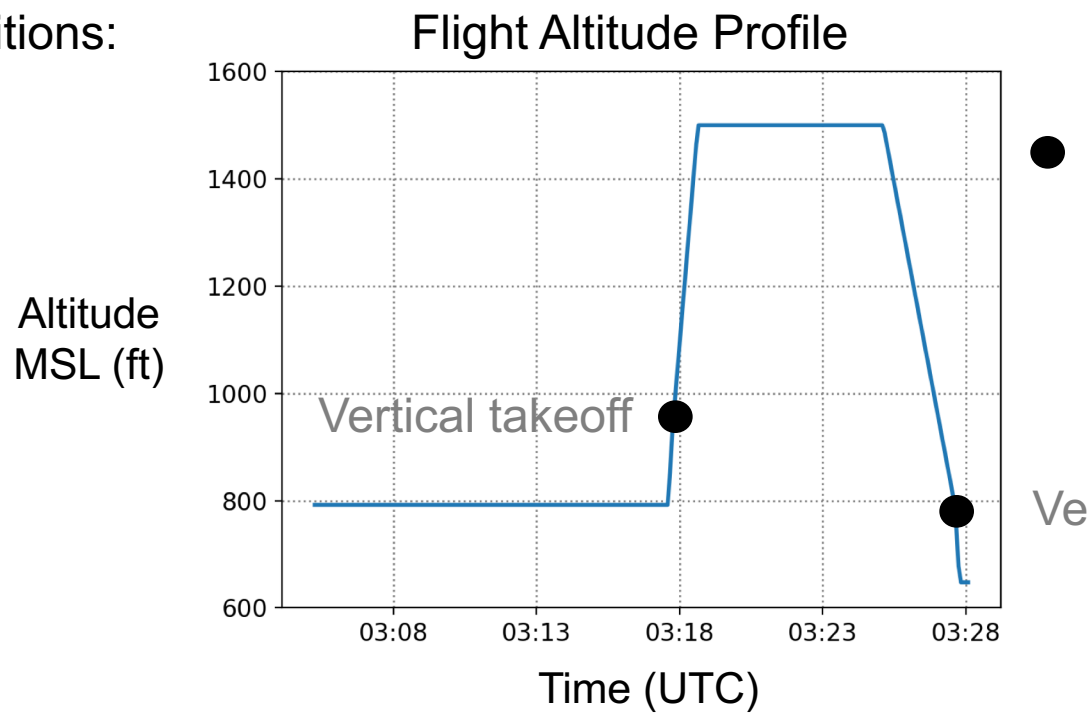


Methodology

Aircraft Characteristics and Trajectory Generation

- e-VToL aircraft type
- Kinematic linear interpolation-based trajectory generator

Cruise conditions:
170kts
1500ft MSL



Methodology

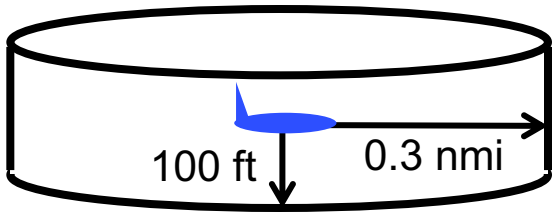
Assumptions

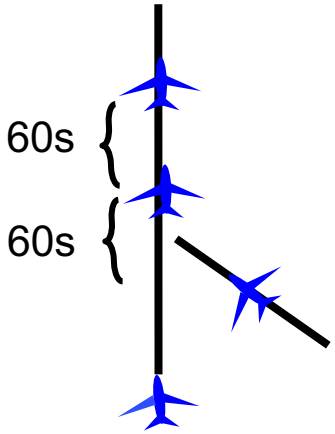
- No uncertainty considered in the simulations
- No trajectory prediction errors
- Simplified kinematic-based aircraft model
- Segregated airspace
- Only UAM-type aircraft considered
- One vertipad modeled per vertiport
- Can immediately use vertipad once aircraft lands/departs
- No vertiport capacity and operations modeled

Methodology

Evaluation Conditions

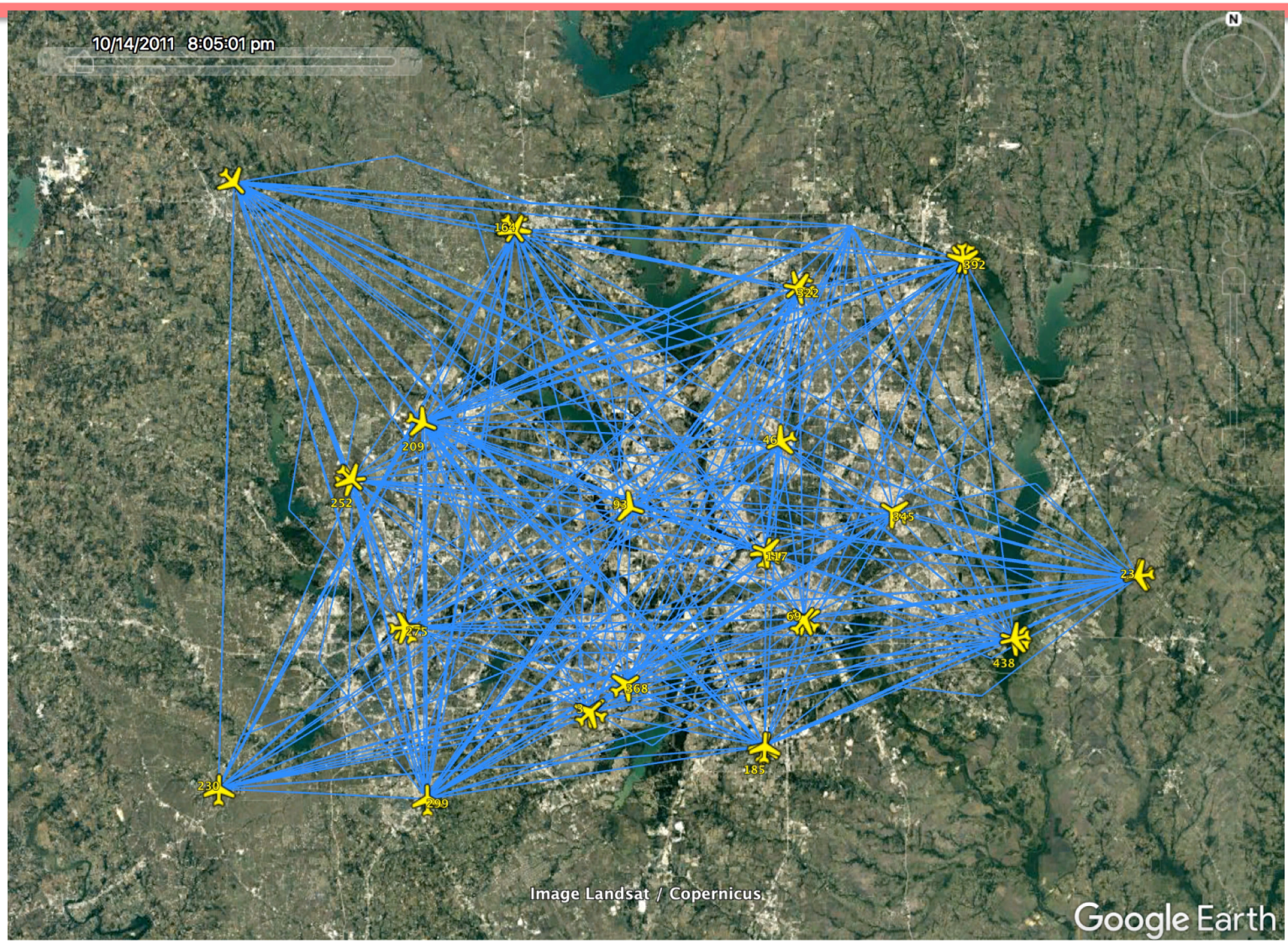
Test Case	Separation Standards	Sequencing Specification	Arrival Scheduling Horizon
1. Baseline	0.3nmi H 100ft V	60s	50min
2. Reduced lateral spacing	**0.1nmi H** 100ft V	60s	50min
3. Reduced temporal spacing	0.3nmi H 100ft V	**45s**	50min
4. Reduced arrival scheduling horizon	0.3nmi H 100ft V	60s	**8min**





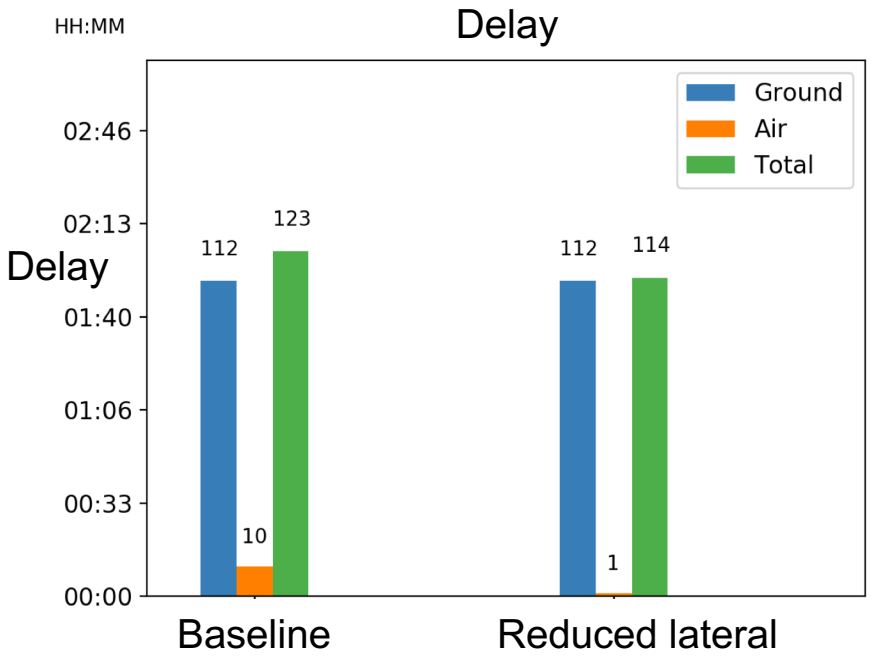
Time at which the ETA at the arrival vertiport is computed and freezed

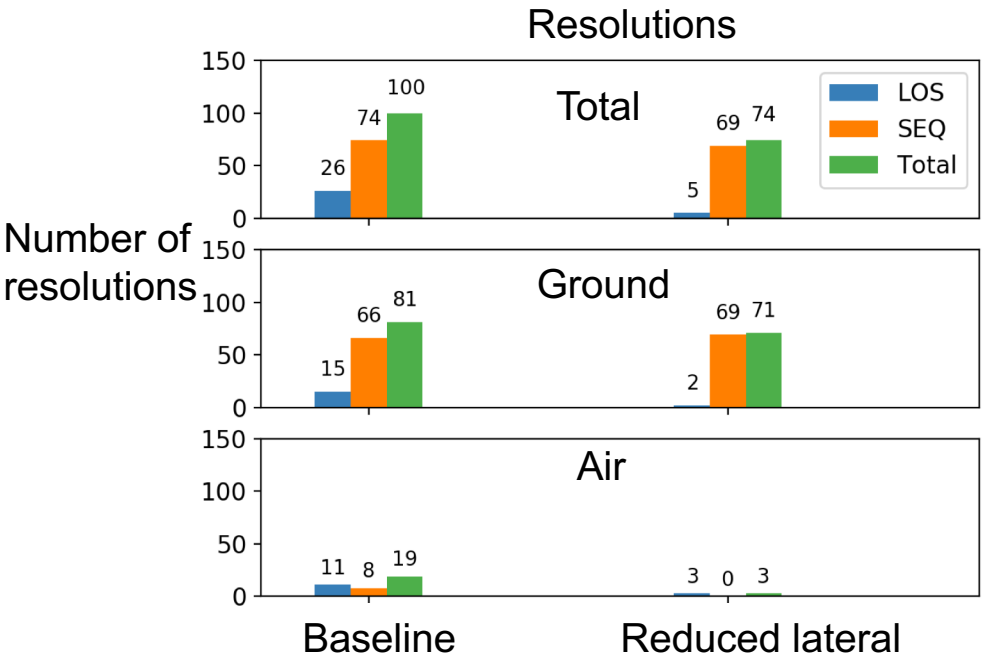
Simulation Results



Simulation Results

Separation standards comparison: 0.3nmi vs 0.1nmi



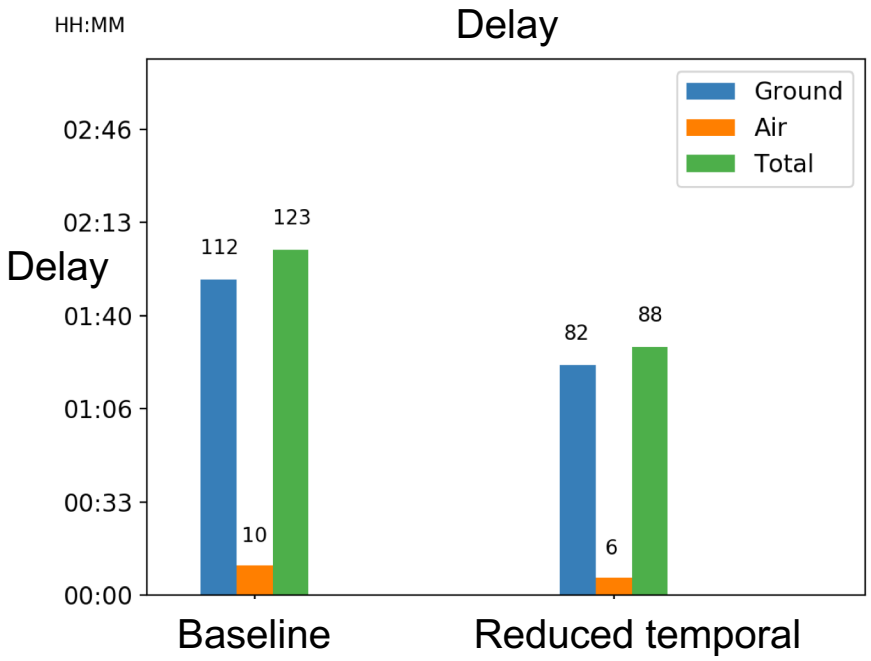


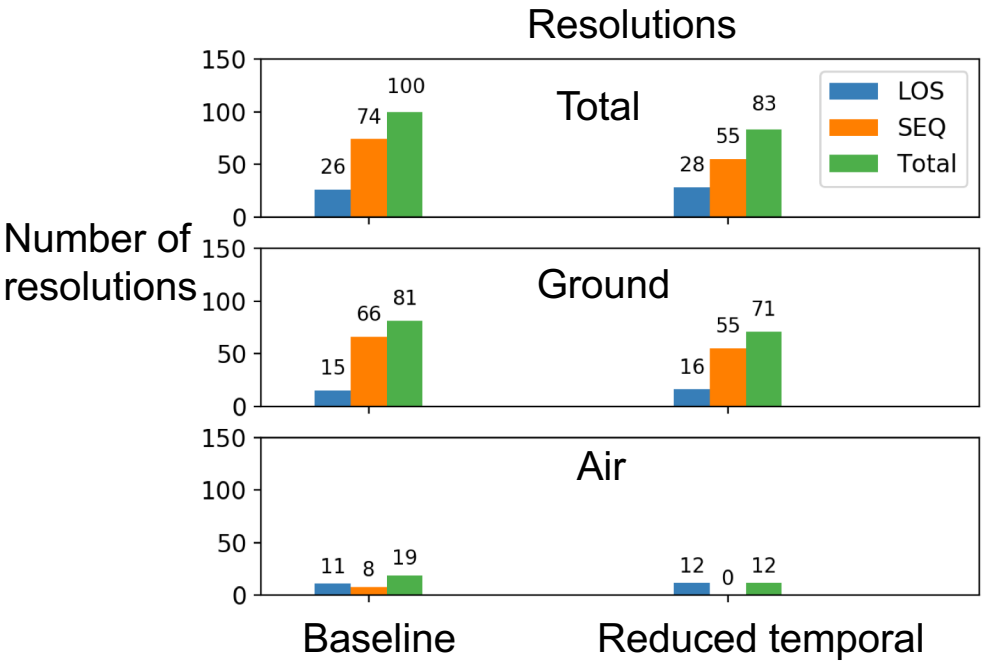
- Constant ground delay
- Less air delay
- Total delay decreased by 7.3%

- Fewer resolutions
- Total resolution number decreased by 26%
- More impact in air than on ground

Simulation Results

Sequencing specification comparison: 60s vs 45s



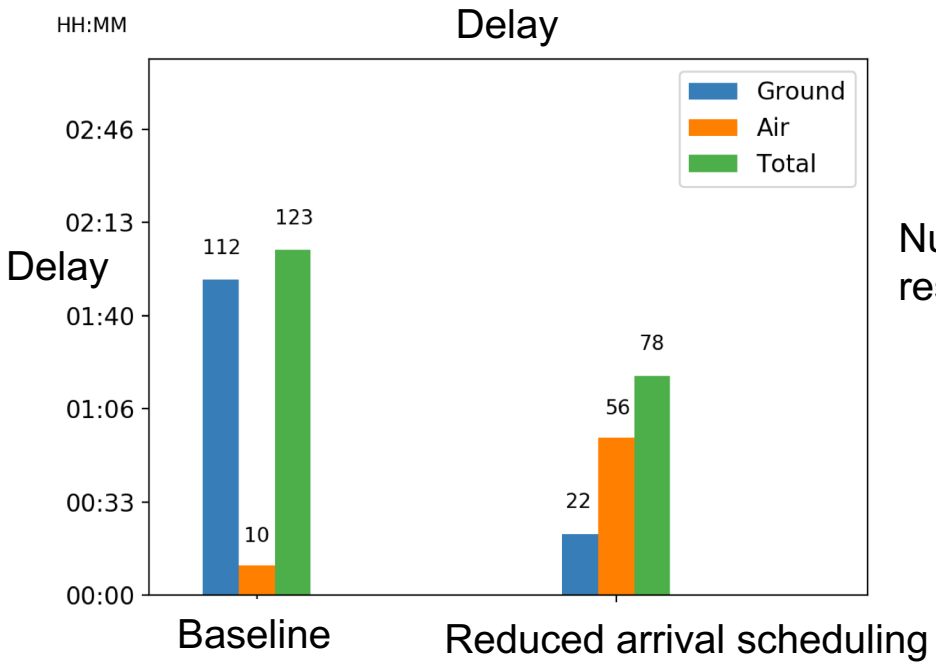


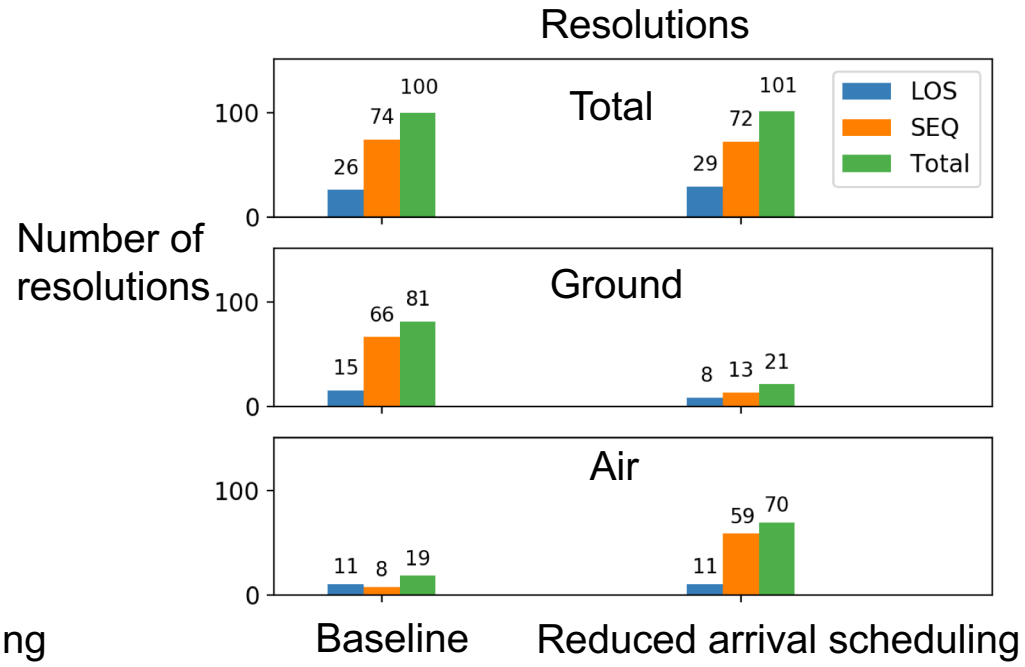
- Decrease of all delays
- Total delay decreased by 28.4%

- Fewer resolutions
- Total resolution number decreased by 17%
- More impact on ground than in air

Simulation Results

Arrival scheduling horizon comparison: 50min vs 8min





- Decrease of total delay
- Shift of ground to air delay
- Total delay decreased by 36.6%

- Similar aggregate resolution numbers
- Impacts on both ground and air

Summary

- Developed an initial implementation of a research platform to explore far-term UAM operations
- Evaluated a research prototype of an autonomous network management and separation concept under different operational conditions
- Demonstrated that AutoResolver's capabilities were effective at solving the designed scenario, under all three operational conditions and for the selected density, without creating any losses of separation
  - Delay and conflict resolution trends were as expected
  - Showed that allowing aircraft to takeoff prior to being scheduled can offer reduced delay values for the network

Future Work

Future work is required to

- Expand further the AutoResolver algorithm capabilities
- Evaluate more complex scenarios looking at
  - Interactions with non-UAM-aircraft in non-segregated airspace
  - Uncertainties
  - Different vertiport and vertipad configurations
  - Model aircraft battery usage

Thank you!

Questions?

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